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CHANGES IN BED OF MISSISSIPPI RIVER

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THE REPORT OF THE MISSISSIPPI RIVER
COMMISSION FOR 1912

THE FLOOD OF 1912
CHANGES IN RIVER BED
OUTLETS
LEVEES
FLOOD LOSSES

PRESENTED BY MR. VARDAMAN

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CHANGES IN BED OF MISSISSIPPI RIVER.

THE FLOOD OF 1912.

The high water of 1912, beginning in March, culminated at Cairo on April 6 and developed a protracted flood below Cairo, extending through April and May. The gauge heights exceeded all previous records from Cairo to the Gulf, except at Vicksburg, where a lower stage was caused by the breaks in the levees on both sides of the river above that point before the arrival of the flood crest.

This flood, which is the greatest of record below Cairo, was due to the coincidence of moderately high waters in the Missouri, upper Mississippi, Ohio, Wabash, Tennessee, and Cumberland Rivers, supplemented by excessive rains covering the alluvial basins and the watersheds of the southern tributaries. The lower tributaries were also at high stages during the passage of this flood. The outflow from the Mississippi through the crevasses returned to the main stream at the mouths of the tributaries whose contributions to the flood were thus somewhat obscured. The stage at St. Louis was unusually high for April, but was still more than 8 feet below the maximum of 1903, and 11 feet below that of 1844. At Cincinnati the stage was 24.3 feet below the maximum of 1884.

A study of the hydrographs of past years shows that the greatest floods at Cairo are invariably produced by the conjunction of floods from a large proportion of the main tributaries, a different combination of these tributaries being found to exist for each flood year. It has never yet happened, as far as the records show, that the maximum floods of each of the principal tributaries above Cairo, or even of a considerable proportion of them, have arrived at the head of the lower valley simultaneously, and from the wide geographical distribution of their drainage areas in both latitude and longitude such coincidence seems highly improbable.

At all stations from Cairo down, the gauge heights would have been greater by varying amounts had the levees remained intact. The duration of the flood of this year was also unusually great, the stage at Cairo being above 45 feet on the gauge for 45 days. The greatest number of days in any previous high water was 49 days in 1897.

Gauge heights do not measure the magnitude of a flood except at the head of the Delta, where conditions as to flow change but little. On the lower reaches of the river the gauge heights manifestly depend largely on the extent of the flood control by the development of the levee system. Consideration should be given to these facts in comparing the recent flood stages with those of earlier years, when large areas were subject to overflow that are now protected by levees, which materially contract the high-water width of the river.

The destructive effect of a flood depends on its height, its duration, and the season of the year when it occurs.

Floods which reach exceptional heights not only threaten the weaker parts of the levees near the top, but when crevasses occur, much greater territory is covered and the escaping flow causes greater damage to the submerged lands and property, owing to the high velocity of flow and greater depths.

Floods of exceptional duration which stand against the levees for long periods of time result in saturation of both the foundations and the levees themselves, which is apt to result in sand boils and crevasses.

Floods that occur late in the season cause damage to growing crops and make replanting after the recession of the water too late for maturing them, whereas an early flood might pass with little damage on this account, even if crevasses did occur.

The alluvial valley is developing rapidly year by year as the result of levee protection, and this in turn means an increasing amount of damage when breaks in the levees occur.

The relative stages of the tributaries above Cairo contributing to this flood are given in the following table, which shows the gauge heights at Cairo and corresponding gauge heights, allowing the proper time interval for the flow, at representative stations above Cairo for 1912 and for the previous great floods. The day and maximum reading for the year are given in parentheses. The bottom line in the table gives the highest known water prior to 1912 for each station.

Year.	Date at Cairo.	Cairo gauge reading (in feet).	St. Louis, 3 days earlier, gauge reading (in feet).	Ohio River, Paducah, 1 day earlier, gauge reading (in feet).
1882	Feb. 26	51.87	27.10 (July 5–32.39)	49.78 (Feb. 26–49.95)
1883	Feb. 27	52.17	25.50 (June 26–34.80)	50.60 (Feb. 25–50.70)
1884	Feb. 22–24	51.79	14.70 (Apr. 9, 10–28.10)	53.95 (Feb. 23–54.25)
1886	Apr. 19	51.02	20.80 (May 13–27.00)	50.00 (Apr. 17–50.40)
1893	May 9	49.33	29.30 (May 3–31.60)	42.30 (Feb. 27–44.30)
1897	Mar. 25, 26	51.72	18.80 (May 2–30.95)	50.90 (Mar. 24, 25–50.90)
1898	Apr. 6	49.78	20.20 (May 23–27.20)	47.10 (Apr. 6–47.30)
1903	Mar. 16, 17	50.57	24.50 (June 10–38.00)	47.60 (Mar. 15, 16–47.60)
1907	Jan. 27	50.33	26.10 (July 25–28.00)	45.00 (Jan. 28–45.70)
1912	Apr. 6, 7	53.95	29.85 (Apr. 5–30.80)	49.40 (Apr. 8–11–49.90)
Maximum gauge readings prior to 1912		1883=52.17	1844=41.4	1884=54.25

Year.	Date at Cairo.	Cairo gauge reading (in feet).	Ohio River, Cincinnati, 5 days earlier, gauge reading (in feet).	Tennessee River, Florence, 3 days earlier, gauge reading (in feet).	Cumberland River, Nashville, 3 days earlier, gauge reading (in feet).
1882	Feb. 26	51.87	58.58 (Feb. –58.58)	13.60 (Jan. 22–29.60)	35.60 (Jan. 22–55.30)
1883	Feb. 27	52.17	54.00 (Feb. 15–66.33)	7.80 (Jan. 28–23.30)	16.70 (Feb. 14–41.60)
1884	Feb. 22–24.	51.79	65.50 (Feb. 14–71.06)	22.00 (Mar. 14, 15–25.20)	42.40 (Mar. 15. 16–48.30)
1886	Apr. 19	51.02	49.00 (Apr. 9–55.75)	18.70 (Apr. 8–28.10)	29.20 (Apr. 10. 11–49.30)
1893	May 9	49.33	47.80 (Feb. 21–54.58)	14.80 (Feb. 17-21.40)	16.80 (Feb. 22–40.80)
1897	Mar. 25, 26.	51.72	40.30 (Feb. 26–61.10)	27.50 (Mar. 19–32.20)	47.20 (Mar. 20–49.25)
1898	Apr. 6	49.78	55.40 (Mar. 28–61.10)	10.90 (Jan. 20, 28, 29–13.80)	19.80 (Jan. 23–38.80)
1903	Mar. 16, 17.	50.57	49.20 (Mar. 5–53.20)	16.80 (Mar. 6–18.82)	37.40 (Mar. 9–40.60)
1907	Jan. 27	50.33	64.50 (Jan. 21–65.10)	4.90 (Mar. 5. 6–14.50)	28.20 (Mar. 3–38.90)
1912	Apr. 6, 7	53.95	46.80 (Mar. 27–53.20)	19.58 (Apr. 3–19.58)	45.30 Apr. 8–46.60)
Maximum gauge readings prior to 1912		1883=52.17	1884=71.06	1897=32.20	1882=55.30

From the stages of the tributaries as here shown and the further fact that these stages were caused by rains covering what might be termed the mid-river districts, it seems obvious that reservoirs at the tributary headwaters would not have been effective in preventing the flood in the Mississippi River below Cairo.

CHANGES IN RIVER BED.

A great flood in the Mississippi River always brings out a variety of opinions as to the causes of the floods and suggestions as to how the disasters that attend them may be avoided. The cause of the floods is frequently attributed to the elevation of the river bed due to the construction of levees.

The commission long since established the fact that there has been no progressive elevation of the bed of the river, but it may be well to repeat here in part what has appeared from time to time in our annual reports.

In the commission report of 1890, pages 3093–3098, will be found a memorandum on the question as to whether building levees along a river causes its bed to rise, and the following extracts give the gist of this discussion:

> The statement is often made that leveed rivers raise their beds higher and higher as levees are raised, and hence that levees will give no permanent relief against overflow. These statements are usually made from theoretical opinions and without a thorough knowledge of the theoretical side of the subject, and probably without any knowledge of the facts of experience, which alone can lead to conclusions entirely safe.
>
> The River Po has long been leveed, and it is often stated that its bed has risen largely in consequence of levees. The following data will show how unfounded is the statement that the bed has risen by amounts that are of much importance.
>
> At the revival of civilization the levees on the Po were complete and continuous from Cremona to the mouth of the Oglio, 94 kilometers, or 58.4 miles. About A. D. 1300 they were carried farther down the river, and in the succeeding centuries to near its mouth. In the present century levees have been systematized as to height. Four hundred kilometers, or 248½ miles, were below the flood of 1872; at the end of 1877 it was expected to reduce this to about 30 kilometers, or 18 miles.

Zendrini, in 1720, observed an extreme low water at Ponte Lagoscuro, only 0.36 foot less than that of 1817; and at the dam of Governolo, near the mouth of the Mincio, the river was 1.3 feet lower than a stage of water of 1609, declared by Bardazzoli to be marvelous.

* * * * * * *

The gauge readings, which have only been kept since 1807, show that there has been no important rise of the bed of the river (since that could not rise without raising the low-water surface) at Ponte Lagoscuro in the 68 years covered, and, in connection with Zendrini's observations, show that there has been no probable rise of any importance since 1720, although the raising of levees has been going on during this period.

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To sum up in reference to the Po, it may be said that during the present century the levees on the Po have been systematized and raised to follow an increase in flood height that in 75 years amounted to about 3 feet along the leveed portion of the river, and that there is some evidence of a small rise in the extreme low-water surface of the river, which may be caused by a rise of the bed. It should be noticed, however, that the rise in the bed (if it really exists) amounts to only two-hundredths of a foot a year, and that the annual cost of raising levees to keep up with it would be but a small part of the annual cost of a complete system of levees.

As to the rise in the flood level as the waters are more and more thoroughly confined, it may be said that this was a necessary result of confinement, that the same thing occurs on the Mississippi, and that it will cease when the levees have been built high enough to contain the greatest floods. On the Po, thus far during the last 75 years the effect of the confinement of waters in raising the flood level has far exceeded any tendency that confinement may have had to reduce flood heights by scouring the bed.

The Rhine is also a river which, below Dusseldorf, has long been leveed, and if levees raise the bed of a river here they should have produced their full effect, as they are rarely broken.

* * * * * * *

Hagen carefully examines the gauge readings at Cologne from 1846 to 1879 and at Dusseldorf from 1800 to 1879 to detect changes in the high and low water heights. Treating the gauge readings by the method of least squares, he found the most probable annual change in the water heights. At Dusseldorf he found that with great probability there was an annual sinking of the maximum high water in each year amounting to 0.3 inch; that the mean stage did not change, and that the annual lowest waters showed with some probability an annual increase of one-twelfth of an inch.

For Cologne he found that with great probability the high waters had sunk and the lowest waters had risen by about the same amounts as at Dusseldorf. A rise of one-twelfth of an inch in a year, or 8 inches in a hundred years, is so small as not to be an important matter in a system of levees, and if the hundred years of table above are taken the rise disappears.

It has often been asserted that the bed of the Hwang-Ho, or Yellow River, of China, has risen above the surrounding country, where it is leveed. The error, originally due to Abbe' Huc, has been repeated by English writers on China. The following extract from a letter to me by Gen. J. H. Wilson (a very competent authority) gives reliable information on the subject:

* * * * * * *

In conclusion, I do not hesitate to say that I can not but believe that Abbe' Huc was entirely mistaken in regard to the silting up of the channel, and that an exhaustive survey would prove beyond a doubt that no such silting as to raise any part of the bed above the adjacent country has ever taken place.

* * * * * * *

From the examination of the Po and Rhine it may be concluded that if their beds rise in the leveed portions (which is not entirely certain from the data), it is at so slow a rate as not to be an important factor in the maintenance of a levee system. With levees 10 feet high, if the bed rose at the rate of 1 foot in a hundred years, the cost of raising a line of levees having the length of the present Mississippi system—about 1,300 miles—by this 1 foot would be but about $4,000,000 distributed over the century, or $40,000 per annum, which is a small part of the annual cost of the system. On the Mississippi the records, while not extending over a period long enough to give final results, do not, so far as they go, indicate that the bed has risen.

The opinion so often held that levees cause a river bed to rise is probably due to the fact that the bed of a river does sometimes rise although leveed, and hence it is concluded that the levees cause the rise. Any sedimentary stream, having a definite

succession of stages and discharges and flowing in its own alluvion, finally takes such a slope as will give a velocity sufficient to enable it to carry its sediment, whether derived from above or from its own banks and bed, farther downstream, without, on the whole, scouring or filling its bed. An average velocity less than this will give rise to deposits in its bed, or if it is crooked it will become straighter, thus in either case increasing its slope and velocity toward their normal values. An average velocity greater than this will scour its bed or cause caving in its concave bends, thus increasing its length and diminishing its slope and velocity to such values as its bed can bear without on the whole scouring or filling. When, therefore, the slope of a sedimentary stream suddenly diminishes from that which it needs for a stable regimen its velocity also diminishes, it drops part of its alluvion, and its bed rises. Thus, when the Mississippi enters the Gulf of Mexico its slope suddenly diminishes, its velocity diminishes, and it builds up bars out in deep water. So the Adige, where it reaches the low plains of the Po, needs for permanence a steeper slope than the country has, and raises its bed above it. In all these cases the bed would rise without levees.

There is one more cause for the rise of bed of a sedimentary river, which, however, acts at a very slow rate. The Mississippi pushes its mouth out into the Gulf at the rate of about 4 miles in a century, and this increase in length requires a corresponding increase in fall of water surface to make the water flow out. An increase of 4 miles in length would, with existing slopes, raise the high-water surface at New Orleans about seven-tenths of a foot. The cost of raising levees to correspond with this rise in the water surface would, as has already been seen, be a small part of the annual cost of the system.

The conclusions here given were derived from comparisons of low-water gauge readings. Further investigations of the same subject have been made by means of special surveys, as follows:

In the general survey of the river made by the commission in 1880–1883 all soundings and elevations between the high-water banks of the river were referred to an established datum plane, and this gave a large number of definite elevations with which later surveys could be compared.

Special surveys were made covering the river from Cairo to Carrollton, a distance of 957 miles, in which 311,336 elevations of the bed were determined and these were compared with those of the earlier survey. While these surveys were made in some cases under dissimilar conditions, which might mask the definite results sought, still the comparisons as a whole show a decided depression of the bed for a large proportion of its length and point to a general enlargement of the cross-sectional area of the stream below the high-water banks.

The results of the comparisons of so large a number of elevations justify the conclusion heretofore stated that there has been no measurable progressive elevation of the bed of the river during the period covered by the investigations cited.

Discussion of this subject in detail will be found in commission reports 1894, 1895, 1896, 1898, and 1899.

OUTLETS.

Another popular solution of the flood problem is the outlet plan. In the early years of the commission's work, much careful consideration was given to this subject and reference thereto will be found in the annual reports of 1881, 1882, 1884, 1885, 1890–91, and 1893.

The following extract from the report of 1893, page 3560, sets forth the views of the commission on this subject after stating the necessity of levees for complete flood control:

> To any other system for the protection of these alluvial lands there are objections, both theoretical and practical, which can not be overcome. Those of a theoretical character are connected with the hydraulic law that a reduction of flood discharge

in a silt-formed channel will reduce its capacity below the point of outlet. This observation has been repeated in the many local comparative surveys of the river bed made by the commission before and after crevasses, or before and after rebuilding the levee made necessary by a crevasse. The difficulties of a practical nature consist of the necessity of continuing any outlet to the Gulf without return to the river at any intermediate point. Such return would merely transfer the danger from one locality to another lower down. The condition thus imposed upon any outlet involves great cost and danger. Any outlet intended to relieve the parts of the river where flood heights are now most dangerous would, in any case, be very long. To have an appreciable effect it would require an excavated channel of large width and depth. As it would traverse tracts of cultivated and valuable land, the cost of expropriation of a right of way would be very great. The cost of the levees which would be required to control it and prevent the permanent continuation of disaster and overflow while flowing through regions which will in a few years be placed under the sufficient protection of a levee system would be very much greater.

When completed, there would be two or more rivers, each presenting the same dangers and requiring the same treatment as the present single channel. The cost of efficient outlets would be greater than the cost of completion of the levee system. When constructed they would either silt up, as do many island chutes, or would enlarge and assume the tortuous type of an alluvial stream, with shifting bars and caving banks. Finally, conceived and executed in defiance of physical law, they would fail as a safe, cheap, or efficient method of abating overflow.

After a review of the progress thus far made in the improvement of a levee system and of the facts developed by the continued surveys, gaugings, and observations of the river, such as the entire absence of evidence of any rise of the bed of the river, the local tendency to shoal where volume is reduced, and the larger discharge now controlled between levees, with an increase of flood heights which does not affect the practicability of a levee system, the commission expresses its continued confidence in the reclamation from overflow of the alluvial lands of the lower Mississippi Valley on the lines now proposed and in progress, as entirely practicable, at a cost which is amply justified by the importance of the undertaking.

The experiences of late years do not justify any material departure from the views thus expressed.

It is evident that an outlet to be effective must be such as to carry the outflow to the Gulf and not return the water to the main stream at some point lower down. The highest point that will satisfy this condition is the mouth of Red River, 765 miles below Cairo, and an outlet at that point would give no relief to the many miles above it. The damage by the flood wave would be done before the point of relief could be reached.

Waste weirs have been suggested for the Mississippi below Red River to carry off a volume of the flood equal in depth to the height of the levees, with sufficient width to deliver a large percentage of the over-bank flow. There is no available site for such a structure above Bonnet Carre. This is so far down toward the end of the Delta that a comparatively small area would be benefited thereby, and the general objections to outlets cited in the commission report quoted are largely applicable here as well.

LEVEES.

For convenience in administration and the allotment of funds for levee purposes, the river front has been divided by the commission into levee districts. The names and locations of these districts, as now established by the commission, are as follows:

1. The district on the right bank from the vicinity of Cape Girardeau, Mo., 54.5 miles above Cairo, to New Madrid, Mo. (71)[1] called the Upper St. Francis levee district.
2. The district on the left bank from Hickman, Ky. (36), to Slough Landing, Tenn. (60), called Reelfoot levee district.

[1] Numerals in parentheses are miles below Cairo.

3. The district on the right bank extending from the vicinity of New Madrid, Mo. (79), to the mouth of the St. Francis (298), called Lower St. Francis levee district.
4. The district on the left bank extending from just below Memphis (244) to the Bolivar-Coahoma County line (365), called Upper Yazoo levee district.
5. The district on the left bank extending from the Bolivar-Coahoma County line (365) to the mouth of the Yazoo (599), called Lower Yazoo levee district.
6. The district on the right bank extending from Helena (306) to White River (385), called White River levee district.
7. The district on the left bank from the mouth of the Yazoo River (599) to Baton Rouge (833), called the Homochitto levee district.
8. The district on the right bank extending from Arkansas River (402) to opposite Warrenton, Miss. (606), called Upper Tensas levee district.
9. The district on the right bank extending from opposite Warrenton, Miss. (606), to mouth of Red River (764), including Palmyra Island, called Lower Tensas levee district.
10. The district on the right bank extending from Red River (764) to Bayou Lafourche (885), called Atchafalaya levee district.
11. The district on the right bank extending from Bayou Lafourche (885) to Orleans levee district (968), called Lafourche levee district.
12. The district on the right bank extending from Orleans levee district (982) to the Gulf (1060), called Barataria levee district.
13. The district on the left bank extending from Baton Rouge (833) to Orleans levee district (960), called Pontchartrain levee district.
14. The district on the left bank extending from Orleans levee district (972) to the Gulf (1060), called Lake Borgne levee district.

The following table, which is similar to that given in last year's report, has been brought up to date and shows the present condition of the levees and the levee operations during the past year, as compiled from the reports of the district officers.

Levee district.	In system.	Built.	Contents, 1911.	Built since by United States.	Built since by local authorities.	Total built since 1911.
	Miles.	*Miles.*	*Cu. yds.*	*Cu. yds.*	*Cu. yds.*	*Cu. yds.*
Upper St. Francis	90.00	55.00	3,448,722	372,902	77,640	450,542
Lower St. Francis	212.00	207.50	26,016,396	484,333	583,601	1,067,934
White River	74.00	74.00	11,346,107	291,732	53,000	344,732
Reelfoot	21.00	21.00	1,713,458	12,826	None.	12,826
Upper Yazoo	98.50	98.50	30,634,397	None.	None.	None.
Lower Yazoo	207.60	188.00	44,703,267	420,260	391,008	811,268
Upper Tensas	192.90	189.01	39,321,789	325,542	1,328,738	1,654,280
Lower Tensas	157.54	150.10	24,647,388	489,705	173,448	663,153
Atchafalaya	127.22	126.50	22,362,015	265,188	483,600	748,788
Lafourche	82.23	81.47	9,772,443	None.	142,893	142,893
Barataria	71.88	71.88	3,715,665	130,770	34,700	165,470
Ponchartrain	125.78	125.78	18,942,550	None.	131,880	131,880
Lake Borgne	78.10	78.09	4,416,321	51,494	84,071	135,565
Total	1,538.75	1,466.83	241,040,518	2,844,752	3,484,579	6,329,331

Levee district.	Lost or abandoned during the year.	Contents, 1912.	Required to complete.	Estimated final contents.	Per cent now built.	Approximate area protected.
	Cu. yds.	*Cu. yds.*	*Cu. yds.*	*Cu. yds.*		*Sq. mi.*
Upper St. Francis	170,850	3,728,414	7,270,690	10,999,104	33.9	700
Lower St. Francis	394,848	26,689,482	4,846,514	31,535,996	84.6	3,500
White River	140,100	11,550,739	5,319,504	16,870,243	68.5	910
Reelfoot	60,032	1,666,252	1,001,294	2,667,546	62.4	310
Upper Yazoo	None.	30,634,397	Completed.	30,634,397	100.0	3,281
Lower Yazoo	1,134,000	44,380,535	11,196,000	55,576,535	79.9	3,367
Upper Tensas	1,348,000	39,628,069	10,328,000	49,956,069	79.3	2,500
Lower Tensas	181,308	25,129,233	4,888,051	30,011,284	83.7	2,080
Atchafalaya	650,611	22,460,292	3,312,027	25,772,319	87.1	6,085
Lafourche	128,000	9,787,336	1,706,351	11,493,687	85.2	2,020
Barataria	54,230	3,826,905	1,194,034	5,020,939	76.2	
Pontchartrain	None.	19,074,430	2,445,991	21,520,421	88.6	1,816
Lake Borgne	41,800	4,510,086	1,291,953	5,802,039	77.7	
Total	4,303,679	243,066,170	54,794,409	297,860,579	81.6	26,569

The "estimated final contents" of the levees given above is based on grades and sections, as provisionally established by the commission.

The loss of levee by abandonment on account of caving river banks, crevasses, or for other causes during the past year, as shown in the above table, was 4,303,679 cubic yards, which amounts to 1.77 per cent of the contents of the existing levees. The loss due to crevasses of 1912 alone amounts to 2,579,330 cubic yards, or 1.06 per cent of the whole yardage.

In addition to the levee districts given in the foregoing table, there is the Homochitto levee district, established by the commission in 1894, extending on the left bank from mouth of Yazoo River to Baton Rouge. Surveys were made of portions of this district in 1895 and in 1910, but no levee work has ever been done in it by the commission.

Under the joint resolution of Congress approved April 30, 1912, the commission contemplates closing crevasses in such levees as exist in this district.

From the stages prevailing in the rivers above Cairo about the middle of March, it was foreseen that the levees on the lower river would be required to withstand an unusual strain from the approaching flood, and every effort was made to prepare them for it. Large forces were organized in each of the districts for raising and strengthening the levees, and work was prosecuted unremittingly until the passage of the flood crest.

The commission established a provisional grade, based on previous high-water records, to which the levees should be built. The ultimate grade necessary to safely pass the maximum flood can only be reached by observing the effect of successive floors, as the levee system becomes more and more effective in flood control. The provisional grade line has always been well above the flood line and also well in advance of the levee heights possible with the funds placed at the disposal of the commission. The flood of 1912 gives new data for fixing a standard high-water and determining a higher provisional-grade line.

The following table shows the height of the levees as compared to the provisional-grade line, the high water of 1912 and previous highest, and estimated high water for confined flood of 1912:

Table of gauge readings of flood heights and provisional grades—Mississippi River—Cairo to Fort Jackson.

Name of gauge station.	Miles below Cairo.	High water, 1912.[1]		Previous highest water and year.	High water, 1912, compared with previous highest.	Estimated high water for confined flood, 1912.[2]	Provisional levee grade.	High water, 1912, below provisional levee grade.
		Date.	Gauge reading.					
			Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Cairo, Ill	0.0	Apr. 6, 7	53.95	52.17–1883	+1.78	55.0	55.20	1.25
Columbus, Ky	21.6	Apr. 5	49.00	45.28–1883	+3.42	49.7	51.30	2.30
New Madrid, Mo	70.3	.....do	44.11	40.27–1897	+3.84	44.6	45.60	1.49
Cottonwood Point, Mo	122.5	Apr. 11–13	42.04	39.96–1903	+2.08	43.0	44.30	2.26
Fulton, Tenn	175.4	Apr. 9	43.31	40.15–1903	+3.16	44.0	44.60	1.29
Memphis, Tenn	230.0	Apr. 6	45.20	40.30–1907	+4.90	48.5	45.60	.40
Mhoon Landing, Miss	276.3	.....do	44.90	42.20–1907	+2.70	47.0	46.80	1.90
Helena, Ark	306.5	Apr. 22	54.30	51.75–1897	+2.55	55.5	56.10	1.80
Sunflower Landing, Miss.	352.7	Apr. 15	50.85	48.00–1903	+2.85	53.0	52.20	1.35
Mouth of White River, Ark	393.2	Apr. 16	56.35	53.70–1903	+2.65	58.9	57.70	1.35
Arkansas City, Ark	438.3	Apr. 12	55.35	52.90–1903	+2.45	57.5	56.90	1.55
Greenville, Miss	478.3	.....do	50.75	49.10–1903	+1.65	52.8	53.10	2.35
Lake Providence, La	542.3	.....do	48.11	46.48–1903	+1.63	50.7	50.48	2.37
Vicksburg, Miss	599.3	.....do	51.65	52.48–1897	−0.83	55.0	55.80	4.15
St. Joseph, La	648.3	Apr. 13	48.60	48.07–1903	+0.53	51.0	52.80	4.20
Natchez, Miss	700.3	Apr. 13, 17	51.40	50.35–1903	+1.05	54.5	56.00	4.60
Red River Landing, La	765.3	May 11, 12	53.20	50.20–1897	+3.00	54.5	54.50	1.30
Bayou Sara, La	799.8	May 11	47.20	43.70–1897	+3.50	48.5	47.70	.50
Baton Rouge, La	833.3	May 11, 13	43.80	40.65–1897	+3.15	45.1	45.20	1.40
Plaquemine, La	854.1	May 11	39.38	36.25–1897	+3.13	40.7	40.70	1.32
Donaldsonville, La	885.4	May 10	35.10	32.75–1897	+2.35	36.0	36.95	1.85
College Point, La	904.5	May 11	30.23	27.95–1897	+2.28	31.4	31.80	1.57
Carrollton, La	957.0	.....do	21.05	19.42–1903	+1.63	22.2	23.00	1.95
Fort Jackson, La	1,039.0	May 3, 4, 7, 11	8.28	8.27–1907	+0.01	9.0	11.00	2.72

[1] The high water of 1912 is the highest known for all stations on the Mississippi River from Cairo down, except at Vicksburg, Miss.

[2] The estimated high water for the 1912 flood confined is deduced from the data now available and may be modified by further experience.

One of the greatest previous floods on a considerable length of the river was that of 1897, during which 38 crevasses occurred. Commenting on this flood the commission stated, "The important fact that the flood waters can be permanently controlled by a system of levees that can be constructed within a limit of expense warranted by the advantages to be gained seems to have been fairly demonstrated by the flood of 1897."

The next flood of large proportion which also made a new record of stage on parts of the river occurred in 1903 and resulted in 7 crevasses.

After a lapse of nine years with but slight damage to the levees from floods comes the greatest of all the recorded floods on the lower Mississippi River. Twelve crevasses occurred in the controlling levees between Cairo and New Orleans. Only two crevasses occurred in the controlling levee on the east side of the river above New Orleans. No crevasses occurred in the Upper Yazoo Levee, 98½ miles long, nor in the Pontchartrain Levee, 126 miles long. One crevasse occurred in the Lower Yazoo Levee, which has a length of 188 miles.

At Point Pleasant, which is at the head of the Lower St. Francis Levee district, the flood poured through a gap which has been left open for several years on account of the refusal of landowners to grant the necessary right of way. A large amount of the damage done in the Lower St. Francis Basin is due to this gap.

The following table gives locations, dates, and dimensions of the crevasses of 1912—the discharges of these crevasses are given in the accompanying tables of discharge results:

Table of crevasses of 1912.

Name.	Location (miles below Cairo).	Date.	Length.	Yardage.	Cause of breaks.
			Linear ft.	*Cu. yds.*	
Upper St. Francis levee district.[1]	.....	Mar. 30, 1912, and later.	21,987	170,850	Overtopping.
Reelfoot levee district.....	41 L	Apr. 5, 1912	5,550	60,032	Do.
Point Pleasant, Mo.[2].....	80 R	.....	1,200	12,000	
Golden Lake, Ark.....	190 R	Apr. 10, 1912			
St. Clair, Ark.....	221 R	Apr. 6, 1912	14,495	329,128	Structural weakness.
Patton or Wyanoke, Ark...	241 R	.....do.....			
Breaks below Whitehall....	.....	.....	.....	53,720	
Modoc, Ark.....	327 R	Apr. 6, 1912	6,280	140,100	Do.
Fergusons, Ark.....	364 R	Apr. 15, 1912			Overtopping.
Knowlton, Ark.....	365 R	.....	315	.....	Caving bank after flood crest had passed.
Lake Beulah, Miss.....	404 L	Apr. 17, 1912	3,200	1,070,000	Sand boils and faulty foundations.
Panther Forest, Ark.....	452 R	Apr. 12, 1912	2,350	151,000	Sloughing off of land-side enlargement.
Salem, La.....	563 R	.....do.....	4,975	427,000	Sand boils and sandy foundations.
Lower Tensas levee district.[3]	.....	.....	.....	11,700	
Torras, La.....	765 R	May 1, 1912	3,800	78,000	Structural weakness.
Hymelia, La.....	930 R	May 14, 1912	4,000	74,000	Sand boils.
Cannon, La.....	1,020	.....do.....	60	1,800	
Total.....	.....	.....	68,212 12.91 Mi.	2,579,330	

[1] Includes all damage to small levees north of Birds Point.
[2] Upper end of levee line destroyed by further caving.
[3] Washed out toward lower end of levee line.

NOTE.—In addition to crevasses enumerated in the foregoing table, it should be noted that numerous crevasses also occurred in levees north of Cairo, on the east side of the river between Vicksburg and Baton Rouge, and on the Atchafalaya River, none of which was under the care of the commission.

The immediate cause of the crevasses of 1912, as well as of previous years, was defective foundations, sloughing, and in only three cases by overtopping. In the lower districts crayfish and muskrats sometimes damage the levees to such an extent as to threaten their stability and even result in crevasses. Borrow pits and other excavations on the land side of the levee, which were permitted in the early years of levee building, are also a serious menace to stability and require constant care during floods. Considerable work has already been done toward their elimination.

Defective foundations may exist far below the base of the levee in strata of sand through which the water percolates and when the head of water in the river becomes sufficiently great, a break through the surface soil occurs and the result is a sand boil which may cause the levee to collapse with little or no warning.

Sloughing is caused by saturation of the levee due to long-continued exposure to the flood waters. It is apt to occur where the base of the levee is so narrow that the line of saturation reaches the land side of the levee above the ground.

Special attention was given to the location and cause of defects which were developed in the levees during the recent flood and full consideration will be given thereto in future work.

The development of the levee system has been carried on by both the Government and the several levee boards as rapidly as available funds would permit, but the top of the levee is still below the provisional grade for 586 miles of its length and the levee is deficient in the cross section contemplated for a large part of the entire line. Some 53,000,000 cubic yards of earth work are still required to bring the levees up to the provisional grade.

The following table gives the areas overflowed in the various levee districts, areas protected by levees, and mileage of levees below commission grade:

Effect of flood of 1912 on levee system, etc.

Levee district.	Length of levee destroyed.	Areas of land overflowed.	Length of levee protected by sacks, etc.	Areas of land saved from overflow by levees.	Cost of high-water protection to United States.	Length of levee below commission grade.
	Linear feet.	*Sq. miles.*	*Miles.*	*Sq. miles.*		*Miles.*
Upper St. Francis	[1] 21,987	429	11.1	271		25
Lower St. Francis	[2] 15,695	2,790	38.6	710		84.95
White River	6,595	850	18.5	60	$121,482.42	60.40
Reelfoot	5,550	310	18.2	0		14.4
Upper Yazoo		0		3,281		None.
Upper Tensas	7,325	1,498	126.0	260	172,709.62	125.0
Lower Yazoo	3,200	2,270		644		109.5
Lower Tensas			16.1		40,732.52	43.38
Deer Park (722 R)	700					
Union Point to Point Breeze (742–755 R)	1,910					
Atchafalaya			3.1		15,235.96	5.84
Torras (763 R)	3,800	1,343		5,588		
Lafourche			.4		14,153.35	9.01
Hymelia (930 R)	4,000	1,320				
Barataria			4.6		16,432.36	49.20
Lake Borgne			3.1		15,207.99	58.88
Cannon (1020 L)	60	2				
Pontchartrain					21,395.03	1.12
Giles Bend					3,304.57	
Homochitto district					2,126.00	
Bayou Sara					3,250.43	
Atchafalaya River					3,921.78	
Bayou des Glaises					26,722.48	
	70,822	10,812	239.7	10,814	456,674.51	586.68

[1] Includes all damage to small levees north of Birds Point, Mo.
[2] Includes levee destroyed at Point Pleasant this year by further caving.

NOTE.—In addition to the sums given in the above table of cost of high-water protection, large amounts were also expended by the several levee boards, the total of which is not available.

The following statement shows the estimated damages to property and other losses, exclusive of levees, due to the flood of 1912:

First and second districts	$6,569,623
Third district	11,345,000
Fourth district	25,000,000
Total	42,914,623

The estimate for the fourth district is lacking in detailed information and should be regarded as a rough approximation, which is probably too high. Furthermore, the total damage cited is by no means all due to breaks in the controlling levee system, but also covers damages in localities not protected by such levees.

So much work remains to be done to strengthen defective foundations and bring the levees up to the provisional grade toward which the commission has been working that nothing can be done for

several years to come toward reaching a higher grade line unless much larger appropriations are made for levee purposes. It is proposed to reach the limits already fixed before taking up the extended work needed for complete control of the greatest floods. It is of first importance that all that has been gained should be held.

As the great flood of the present year passes away two conspicuous facts appear. The first is that the present levees withstood the flood with surprising success. As will be seen by the table herewith the percentage of loss of levees is small. It is true that in many cases the levees were held only by temporary additions applied with much labor and expense. The experience of the past year further emphasizes the necessity of an increase in height and strength of the levees over the whole fifteen hundred and odd miles of their length. The commission has had this in view from the beginning of the work. Better foundations, better material, increased cross section, and more secure protection have always been kept in mind. Concrete revetment of the river slope of the levees, such as used on the lower reaches of the river, and sheet piling in construction of foundations may also be required in certain localities. With these improvements made, there is no reason why the river may not be controlled in the future even during floods as great as the one just gone by. The measure of flood protection that has been realized in the past fully justifies the work that has been done.

For a time more liberal allotments for the building and protection of levees than have heretofore been made will be required. The riparian landowners, impoverished by overflow and consequent loss of crops, will be less able than heretofore to restore their broken levees and much less able to build the greater ones required for future protection.

Under these conditions it is apparent that the readjustment of the relations of the United States and the riparian communities whereby the latter would assume the whole burden of maintaining the levees, as was suggested in the last report of the commission, must be deferred until the levee system is brought much nearer to the final grade and section.

While the levees have a certain degree of utility in the improvement of the channel and are necessary to "promote the interests of commerce" by providing landing places for the interchange of traffic in times of flood and protecting the lines of railway behind them, their immediate and main value is in the protection of the alluvial lands for the benefit of their owners. But it should be borne in mind that the people residing in the alluvial valley contribute to the extent of their ability and upon the whole expend more money for levee purposes than the Government does.

The sum of the above means that we must go on with levee construction in the way which has justified itself by so many years of successful control of Mississippi floods, but with increased energy, larger expenditures, and better work. In that way only can we justify what we have already done and preserve and continue for the people of the valley, and through them the people of the whole country, the prosperity and happiness which have resulted from the beneficent work done in the past.

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